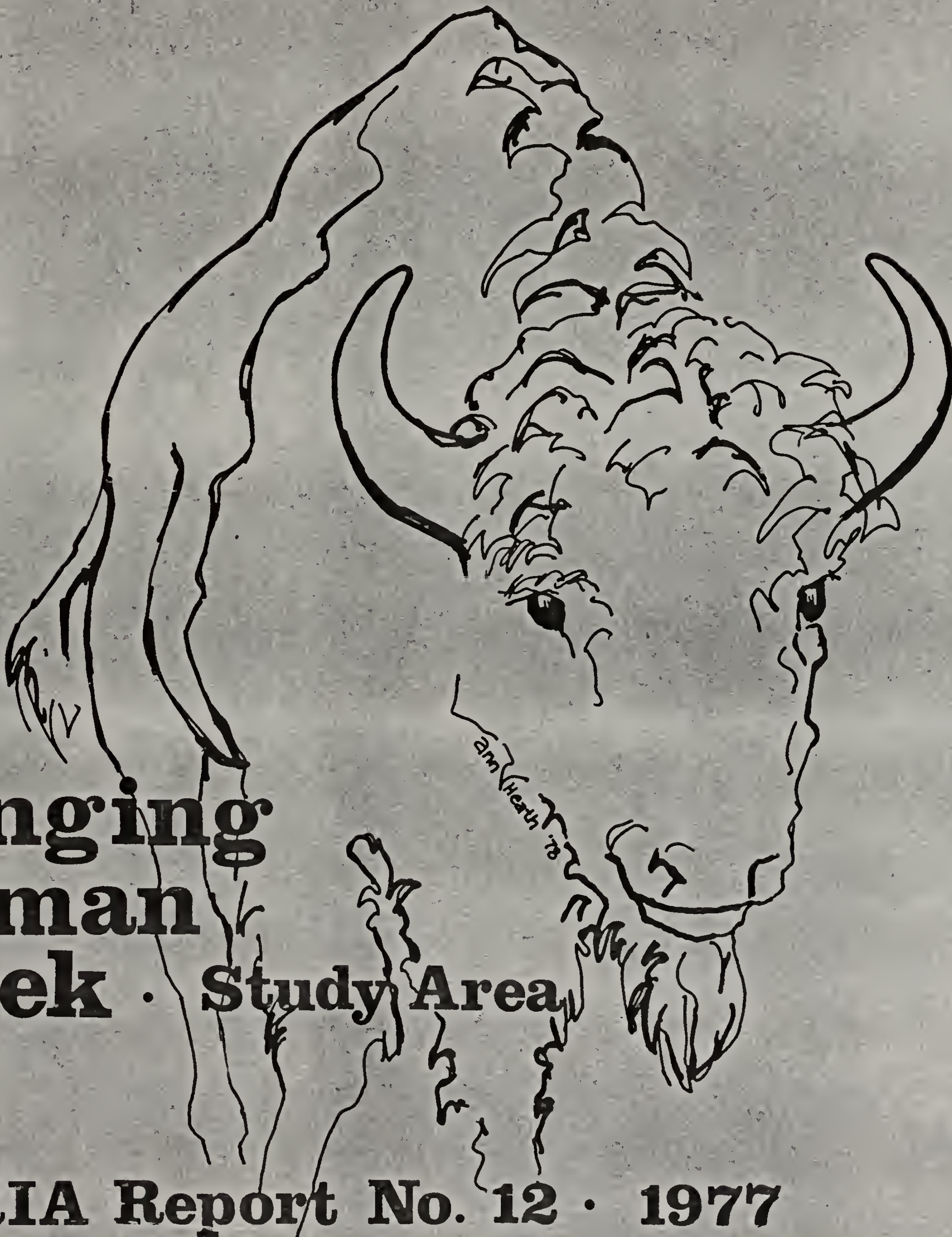
RESOURCE & POTENTIAL RECLAMATION EVALUATION

SUMMARY



Hanging Woman Creek · Study Area

EMRIA Report No. 12 · 1977

UNITED STATES DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT
UNITED STATES GEOLOGICAL SURVEY

EMRIA

(Energy Mineral Rehabilitation Inventory and Analysis)

EMRIA is a coordinated approach to field data collection, analyses, and interpretation of overburden (soil and bedrock), water, vegetation, and energy resource data. The main objective of the effort is to assure adequate baseline data for choosing reclamation goals and establishment of lease stipulations through site-specific preplanning for surface mining and reclamation.

This report is prepared through the efforts of the Department of the Interior, principally by the Bureau of Land Management and Geological Survey. Assistance is also provided by other federal and state agencies.

Reports under this effort are:

EMRIA Report Number, Year

1-75	Otter Creek, Montana	10-77	Beulah Trench, North Dakota
2-75	Hanna Basin, Wyoming	11-77	Pumpkin Creek, Montana
3-75	Taylor Creek, Colorado	12-77	Hanging Woman, Montana
4-75	Alton, Utah	13-77	White Tail Butte, Wyoming
5-76	Bisti West, New Mexico	14-77	Potter Mountain, Wyoming
6-76	Foidel Creek, Colorado	15-77	Henry Mountain, Utah
7-76	Red Rim, Wyoming	16-77	Emery, Utah
8-76	Bear Creek, Montana	17-77	Kimbeto, New Mexico
9-76	Horse Nose Butte, North Dakota	18-77	Fish Creek, Colorado

Reports are available from the following BLM State Offices:

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136 South Temple
Salt Lake City, Utah 84111

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ACKNOWLEDGEMENTS

The Hanging Woman study report is unique in the EMRIA program. All other study reports have been completed by the U.S. Bureau of Reclamation, while responsibility for producing this report was with the BLM. The study site was selected in FY 76 by the Montana State Office. At that time, Hanging Woman and one other site were considered to have number one priority. Funding and USBR personnel restrictions prevented studying both sites in the conventional manner.

At the same time, the Branch of Coal Resources, Geologic Division, U.S. Geological Survey was scheduled to map the Quietus and Forks Ranch 7 1/2 minute quad sheet for coal resources. We were also able to persuade the Montana Bureau of Mines and Geology to alter their drilling program to take in the study site. With the promise of solid cores, the Branch of Regional Geochemistry, Geologic Division, USGS, became interested in the project. The Montana District, Water Resources Division, USGS, were already working under a joint BLM/USGS agreement, thus it was possible to direct their efforts to the area.

All that remained was the crucial part of collating the report and the responsibility for production. This became a joint responsibility of the Division of Resources, Montana State Office and the Rehabilitation Data Staff, Denver Service Center.

The only problem that developed with this approach was the difference in "study site" boundaries. Geologic Division mapped on the original BLM tract selection. The hydrologic studies and soil survey information was developed for the entire watershed. The area mapped by Geologic Division in the only area that has strippable coal and has the potential to be disturbed. The entire watershed needed to be investigated to determine the hydrologic characteristics.

This report is truly an interagency cooperative effort. Without the overwhelming support, coordination and dedication of all the above, the report could not have been published.

INTRODUCTION

This report is to present the reader with a brief, nontechnical summary of conclusions and recommendations for the detailed studies on the Hanging Woman Creek study area. Backup data may be found in the main report.

HANGING WOMAN CREEK STUDY AREA

The Hanging Woman Creek study area lies approximately 40 miles (64 km) south of Ashland, Montana, 30 miles (48 km) northeast of Sheridan, Wyoming, and about 4 miles (6 km) north of the Montana/Wyoming boundary. More specifically, the study area under consideration is the East Trail Creek drainage in southeastern Big Horn and southwestern Powder River Counties.

The area is comprised of 21,960 acres (8894 ha), all or in parts of

T8S, R43E, Sections 35, 36
T9S, R43E, Sections 1, 2, 11, 12
T8S, R44E, Sections 26, 27, 28, 29, 31, 32, 33, 34, 35, 36
T9S, R44E, Sections 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 21, 22, 23, 24
T9S, R45E, Sections 6, 7, 8, 17, 18, 19, 20, 21, 28, 29

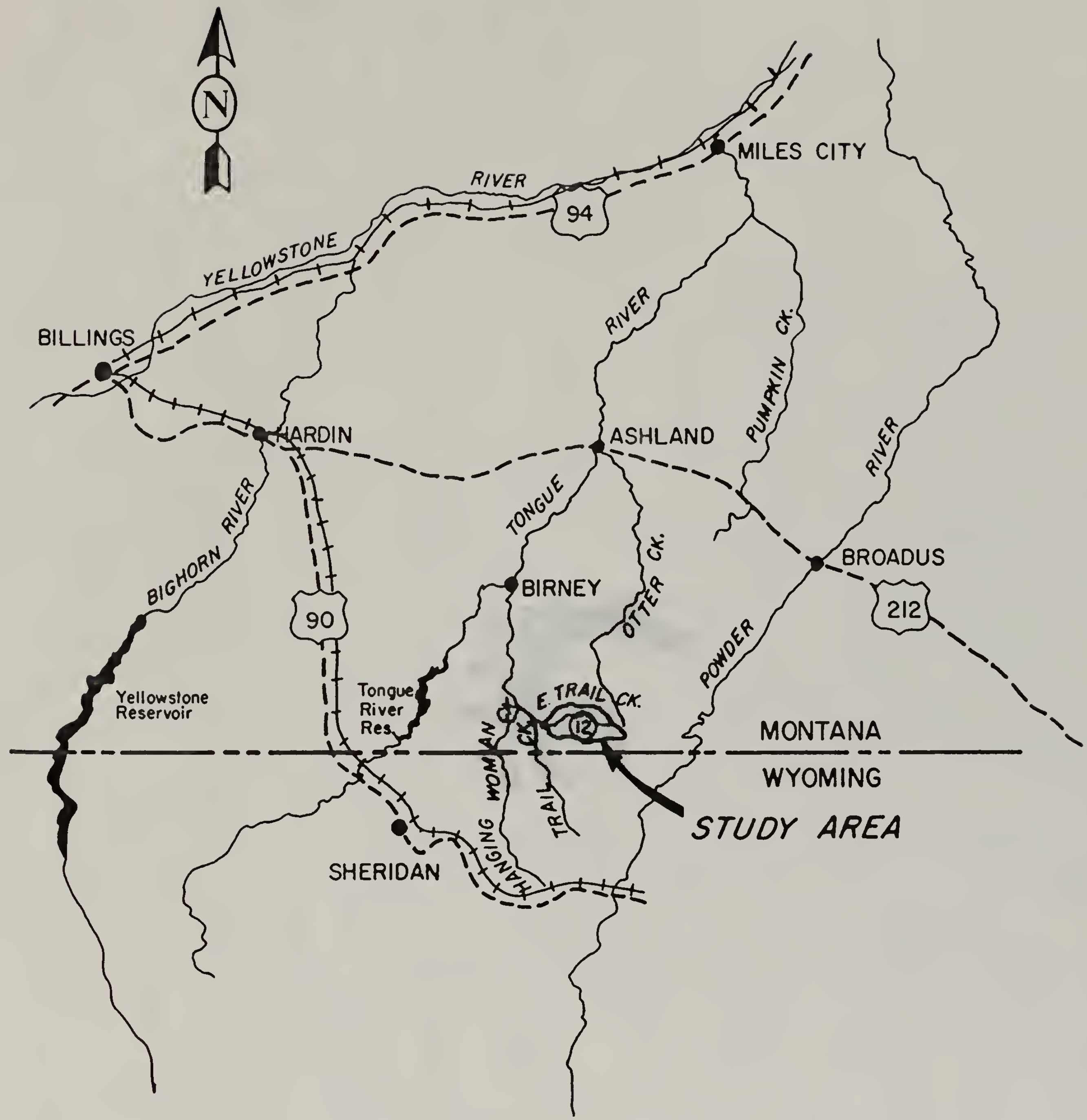
The study area (EMRIA Study No. 12) is shown relative to major landmarks in Figure 1.

PHYSIOGRAPHY

The Hanging Woman Creek study area is the East Trail Creek watershed. As illustrated in Figure 1, East Trail Creek is tributary to Trail Creek which in turn is tributary to Hanging Woman Creek which flows into the Tongue River at Birney. This area is in the Missouri Plateau section of the Great Plains physiographic province. Generally, this province is characterized by a series of benches which progress up to flat topped narrow divides between major stream valleys. These flat topped ridges constitute the remains of a once more widely extended plateau surface, which have been intricately dissected to create steep slopes adjacent to stream valleys.

The relief in the study area is approximately 600 feet (183 m), ranging from 3560 foot (1085 m) elevations along Hanging Woman and East Trail Creeks to 4200 foot (1280 m) elevations in the uplands along both creeks.

The ridges are remnants of an old upland surface that has been dissected leaving the margins of the uplands delineated by the outcrops of resistant sandstone ledges. The flat top ridges are generally protected by clinker zones created by burning coal seams.



(12) Hanging Woman Creek Study Area

Hanging Woman Creek Coal Field

Figure I. General Location Map of the Hanging Woman Creek Study Area.

The valley sides are characterized by gentle to moderately steep slopes, with smooth, coalescing alluvial fans, footslopes, and stream terraces. East Trail Creek is entrenched to a depth of 6 1/2 to 16 feet (2 to 5 m) into alluvial materials derived from soft, sedimentary rocks.

The lithology of the surrounding area comprises sandstones, mudstones, and shales within the Tongue River Member of the Fort Union Formation and limited outcrop of the Wasatch Formation, both of Tertiary age. There is a limited area of clinker outcrop near the west end of the study area.

Stream gradients are relatively steep with the dominant stream pattern being dendritic.

HISTORICAL DEVELOPMENT

Strip mining of sub-bituminous coal near Colstrip, Montana, has taken place intermittently since 1923. Through 1958, coal in the area was mined by Northwest Mining Comapny, a subsidiary of the Northern Pacific Railway (now Burlington Northern, Inc.) for use in coal-fired steam locomotives. Mining was discontinued when the steam locomotives were replaced by the diesel-electric engines. In 1959, the mine, equipment, and the town of Colstrip were sold to the Montana Power Company (MPC). Mining was resumed in 1968 by Western Energy Company (WEC), a subsidiary of MPC. From 1969 through 1977, WEC's Rosebud mine produced a cumulative total of 45.8 million tons. Reserve estimates in 1974 ranged from 850 million to 1 billion tons for WEC leases in the Colstrip coal field. Projected yearly production for the Rosebud mine will be 18 million tons by 1980.

The Decker West strip mine is one of the most prolific producers of coal in North America, and delineated reserves (3.1 billion tons) make the Decker area the most important coal district in Montana. Production began at West Decker in 1972 with an output of 800,000 tons from the Anderson-Deitz No. 1 combination coal seam, and by 1977 cumulative production had amounted to 42 million tons.

Decker West is owned by Decker Coal Company, and the mine is operated jointly by Peter Kiewit Sons and Pacific Power and Light, each with a one-half interest. A Decker East mine began production in the spring of 1978. Decker West and East mines are located within the Decker and Deer Creek coal deposits, respectively. A Decker North mine is scheduled to open in the near future north of the Decker mine. Strippable reserves at the Deer Creek deposit are 410 million tons; those of the Decker deposit, 2.24 billion tons.

PRESENT LAND USE

Agriculture within the study area is confined to cattle grazing with some native hay harvested along flat bottomed drainages. Along the road which extends south and east of Quietus, which is in the extreme easterly extent of the Upper East Trail Creek drainage, are several hay meadows. These are primarily in Section 35, T8S, R44E; Sections 1, 2, 12, T9S, R44E; and Section 7, T9S, R45E. There are a few small irrigated hay fields.

Surface ownership is primarily private with isolated tracts of federal and state lands. With the exception of approximately 1 1/2 mi^2 (4 km^2), coal ownership lies with the Federal government.

FUTURE DEVELOPMENT

The Montana State Director of the Bureau of Land Management has released the proposed federal leasing action for the Powder River area. This area includes the Hanging Woman Creek coal field, which in turn includes the Hanging Woman Creek study area (see Figure 1 for locations).

The proposed leasing areas are subdivided into levels according to priority and planned lease dates. Level 1 and 2 lease tracts are scheduled to be leased prior to 1990. Level 3 tracts, which includes the Hanging Woman Creek coal field, are not being proposed for lease at this time.

HANGING WOMAN CREEK COAL FIELD

About 30,000 acres (12,150 ha) of the Hanging Woman Creek coal field is underlain by strippable coal of sub-bituminous C rank, principally in the Anderson and Dietz coal beds. Additional small areas are underlain by strippable deposits of coal in the Canyon, Smith, and Roland coal beds, but these deposits are so small compared with those of the Anderson and Dietz that they should not alter the economic potential of the Hanging Woman Creek coal field significantly.

Coal Resource Occurrence maps showing coal thickness, overburden, structure and resources of each major coal bed in this area are presently being prepared by the U.S. Geological Survey and will be published in the near future.

The most important bed is the Anderson coal bed which is 15 to 36 feet (4 to 11 m) thick and is essentially free of partings. Although much of it has burned, resulting in large masses of baked and fused rock called clinker, large areas of unburned coal still remain at shallow depth. These deposits are strippable in and adjacent to the major tributaries of Hanging Woman Creek.

The Dietz coal bed is generally 50 to 70 feet (15 to 21 m) below the Anderson coal bed but is locally as much as 120 feet (37 m). In most of the Hanging Woman Creek coal field, it is 7 to 18 feet (2.1 to 5.5 m) thick, generally thickening northward. In the southwestern one third of the area it splits into 2 to 4 beds ranging from 3 to 5 feet (1 to 1.5 m) thick, and therefore has little economic potential. The Dietz coal bed is probably strippable in and adjacent to the major tributaries on the east side of Hanging Woman Creek.

MINING EFFECTS AND RECLAMATION ALTERNATIVES

Hydrology

The effects of surface mining on the area hydrology depend on the depth to which coal beds will be stripped and the areal extent of mine development. Two mining alternatives assume mining of the Anderson coal bed alone or mining of the Anderson plus one or two coal beds below the Anderson.

Surface mining of the Anderson will drain the saturated overburden and the Anderson coal bed adjacent to the mined area. The mine floor will be lower in altitude; therefore, the hydraulic gradient will be from the alluvium to the mine in most surface-mined areas. Water in the alluvium could be diverted into a mine even though surface mining did not extend to the alluvium. Assuming a surface mine approximated by a well one-half mile (.8 km) in radius, mine inflow is estimated by a form of Darcy's law to be less than 0.7 ft^3/s (.02 m^3/s). However, this flow should gradually diminish to less than 0.1 ft^3/s (.003 m^3/s) as hydraulic gradients approach equilibrium conditions.

The area of greatest water-level decline in wells can be expected to be to the east, upgradient from any potential surface mine. Depending upon the extent of mining, 17 stock wells or springs could become dry. Replacement wells of similar yields could be completed in one or more water-bearing zones of the Tongue River Member. The water quality generally could be expected to be better than water from wells presently in alluvium.

East Trail Creek and its intermittent tributaries will continue to be losing streams in the study area as the alluvium is drained by mining. Intermittent streamflow is likely to be slightly decreased as water infiltrates to the alluvium. Streamflow downstream from the study area could be increased if mine drainage is returned to East Trail or Trail Creek. Because the stream would be above the water table, the drainage would likely infiltrate into the alluvium or clinker over a short distance. As discussed above, however, channel erosion would need to be prevented at points of reintroduction during periods of heavy dewatering and heavy rainfall.

Floodwater would need to be diverted around a mine. Diversion works would need to be designed to carry the natural sediment load as well as to be noneroding. Diversion channels could be designed to minimize infiltration.

Post-mining water-quality changes are to be expected in both surface and ground water. Surface-water quality downstream from the potential mine could be degraded by poor quality water from mine drainage and by sedimentation or erosion in the event of improper flood control diversion.

Spoils from strip mining also could cause changes in ground-water quality. The character of these changes is difficult to predict without mineralogical data of the replaced spoils. However, recharge to existing

shallow aquifer units through replaced spoils during post-mining conditions may be small. Even so, placement of toxic materials and hazardous overburden minerals between the soil zone of oxidation and the present level of ground water should mitigate adverse alterations of ground-water quality caused by toxic spoils. The active mine will act as a discharge area for shallow ground water; however, any water polluted by mining operations, such as by explosives or by fuel and oil spill, may percolate to deeper aquifers in areas where the head gradient is downward.

Water problems associated with surface mining the Anderson plus one or two other coal beds would be similar, but more extensive than if the Anderson alone were mined. A deeper mine would extend farther into the alluvium and would produce more water. Probably more than twice as much water would be produced from the mine and its disposal would have to be controlled to prevent downstream erosion. Water levels in the alluvium downstream from the area would be lowered more severely, which could decrease hay production and injure plants whose roots extend to the water table.

Reclamation of spoils appears to be possible using seasonal precipitation alone. Revegetation on the spoil piles can be improved by surface conditioning and top-soiling. Surface conditioning reduces surface runoff and maximizes utilization of precipitation. Top-soiling maximizes use of pre-existing soil.

Sediment Yields

The following discussion is based on the assumption that, if the area is mined, the primary post-mining use will be rangeland.

The assumption was also made that, if the area is mined, it will be graded, covered with topsoil or otherwise suitable growth media, and seeded with adapted grasses. Close-spaced contour furrowing or gouger pitting may be necessary to control runoff from and erosion of soils that are silt loam or finer-textured or any soil that is compacted. Implementation of these practices would reduce the frequency of floods that would be large enough to damage the post-mining channels and valley floors and would minimize the chance of increasing sediment loads downstream from the area.

An important problem to contend with in the rehabilitation plan for the area is that much of the land surface will be lowered by mining. This will occur because, in those areas where the overburden is less than about 150 ft (46 m) thick, the overburden will not expand enough to fill the void left by excavation of the coal bed which is approximately 30 ft (9 m) thick. This will result in a depression in lower parts of the mined area where the overburden is thinnest. If this depression is not filled with earth materials, at least so that streams can cross the depression, ponds will form in the lowest parts.

Anywhere that the gradients of stream channels are increased after mining, such as where the channels enter a lowered area, there is potential for the initiation of gully erosion which would migrate headward in the alluvium upstream from the mined area. The resulting gully would drain ground water from the alluvium and thus deteriorate the productivity of the valley floor.

The lowering of the land surface may require that channels be stabilized by cutting and filling to minimize increases in gradients and/or by constructing widened channels where the gradients are increased so that normal flows would be relatively shallow. Also, most channels of East Trail Creek have gradients that are steep enough to cause erosion in channels of the same widths that were situated in unstable materials such as newly placed spoils and soils. Lining the channels may be necessary to control erosion in some places where the gradients are increased. A thorough discussion of the hydrologic effects of a lowered land surface appears in the final environmental impact statement for mining that is planned near Decker, Montana.

Another potential problem, which could result in large increases in sediment discharge below the mining area, involves the diversion of the channels of Trail Creek and East Trail Creek if the coal underlying those valley floors is mined. Diversion channels located at one side of the valley floor would have steeper gradients because they would be relatively straight as opposed to the meandering of the natural channels. Installation of stable linings and/or drop structures as discussed in the previously mentioned environmental impact statement would minimize erosion and sedimentation problems in diversion channels.

Implementation of the erosion-control measures that were discussed and installation of sediment retention ponds immediately downstream from raw-spoil banks and other areas where erosion cannot be controlled should minimize any increase in sediment discharge to Hanging Woman Creek. Retention ponds may not be needed after a period of perhaps 10 years when perennial grasses have come into equilibrium with their environment and stable soil structure has reestablished. Any drop structures or channel linings may require periodic maintenance in order to remain functional in the future.

Climate

There is sufficient precipitation to support reclamation efforts. Irrigation would not be required except perhaps in the driest years. The cost of irrigation, however, could probably not be justified on this basis. It would probably be more economically reasonable to have an occasional failure and replanting than plan large-scale continuous irrigation.

The area does have a relatively short growing season, however. This factor will probably be the greatest single constraint to reclamation success. Only July and August are free from average minimum temperatures

less than 32° F. This implies less than 90 continuous frost-free days. Mean monthly temperatures are greater than 32° F from May through October, suggesting a growing season less than 180 days. The actual growing season, depending upon plant species is from 90 to 180 days.

There is sufficient snow in the area to consider the possibility of shaping spoil to trap snow. This would have the effect to delaying melt and increasing soil moisture availability into the spring and summer.

Soils

It is important that productive topsoil is saved to replace on the land surface following mining. A productive topsoil contains the properties necessary to obtain a rapid and effective revegetation. Revegetation is more rapid and permanent, and site stability is more certain with the use of a fertile topsoil with good water infiltration and holding properties. Also, the final soil cover will determine future potential use and management needs of the land following mining. Therefore, care must be taken to select the most suitable topsoil material available for final placement on the mined land surface.

Soil depth needed on the reconstructed land surface will depend primarily upon the future use of the land. If the land is to be used for agriculture, the land should be reconstructed with a depth of soil suited to the rooting depth of crops adapted to the area.

If the land is to be returned to grazing land, the annual depth of moisture penetration in a typical soil would be a reliable criteria to determine soil depth needed. In many situations, this will be the same as the depth of lime accumulation in the soil.

As discussed previously, soil moisture penetration ranges from 8 inches (20 cm) to 33 inches (84 cm) in some of the deeper soils. In some of the shallower soils on breaks and gently sloping uplands, soil moisture penetrates the entire profile. This would suggest that topsoil should be replaced to these depths if reconstruction of the specific site is the reclamation goal.

Seven percent of the acreage lacks any suitable source of topsoil. This includes the rock outcrop, shale outcrop as well as the Kyle and Pierre clays.

One-third of the area (32%) is covered with soils that are a very shallow source of topsoil (less than 10 inches (25 cm)). This includes primarily the Midway and Heldt series.

However, there is a large source of topsoil material from moderately deep and deep soils in the study area. These are primarily the Thedalund, Thurlow, and McRae series. All available topsoil material (including suitable material within 60 inches (152 cm) of the surface) is of sufficient quantity to cover the study area 20 inches (51 cm) deep.

Previous EMRIA studies in Montana (at Otter Creek and Bear Creek) have shown an ample supply of suitable topsoil substitute material, usually near the surface of the overburden. The exact location of this borrow material must be located within a detailed inventory prior to mining. According to the section in this report on overburden chemistry and mineralogy by USGS, there should be more than sufficient overburden material on this study area to use as a soil substitute.

Reconstruction of the mine land provides an opportunity to make the land more productive and more useful than before mining. This is done by (1) shaping the spoils to suit the intended use of the land, and (2) replacing present shallow soils with a soil depth that will allow vegetation a normal response to climate.

The chemical composition of the soils appears to be favorable for stockpiling and land reclamation. The only exceptions are the soil series, Arvada, Bone, and Vananda. These three soil series are judged on the basis of the taxonomic description to be a poor-to-unsuitable topsoil resource because of high salinity. This salinity condition, however, was not confirmed by chemical analysis. A conservative stance would be not to use soil materials from these series as top dressing but to bury them at a depth beyond plant roots. All of the other soils in the study area are alkaline in reaction. The overall trace-element composition of soils in the study area is similar to soils developed on the Fort Union Formation in other parts of the Northern Great Plains and in the Powder River Basin of Montana-Wyoming. Soils throughout the region are widely used for range, pasture, and small grains without ill effects except for very local salinity-problem areas.

Other soil series in soil group 1 may have at least moderate salinity conditions in the subsoil. These materials should either be buried at a depth beyond normal plant-rooting depth or should be diluted by mixing with nonsaline materials. If the mine-reclamation plan can provide for temporary irrigation for the first few years, then saline materials should be placed in the lower parts of the valley where irrigation water may be more readily available to leach the soil. Final surface grading of materials with potential salinity should leave only very gentle slopes so that leaching water will percolate downward in the profile rather than laterally downslope, thus leading to the development of a saline-seep area elsewhere.

In some situations, it would be desirable to have a buffer layer of soil material (or suitable substitute material) between the topsoil and the overburden. This would occur if saline or sodic overburden is located at the surface of the reshaped overburden. Research conducted by the ARS, USDA, Mandan, North Dakota, has found sodium to migrate upward (about 6 inches (15 cm) in 3 years) from a sodic overburden to a nonsodic topsoil. Therefore, in such cases, a compensating buffer layer of subsoil, or a layer of low salt, low sodium overburden would be desirable. A generous layer of soil material replaced on the surface would accomplish the same thing.

The reshaping of spoil-material contours should provide for moderate slopes particularly on south and southwest aspects. These slopes represent some of the more severe survival conditions for plants because of the excessive soil temperatures that are possible, and because the limited precipitation that is typical of the region is subject to excessive runoff if the slopes are too steep.

Careful consideration should be given to plans for reconstruction after mining of bottomlands now occupied by trenched channels and adjacent alluvial terraces. Deepening and widening of the channel of Trail Creek has eliminated frequent flooding of adjacent lands. The channel bed now appears to be aggrading. Grass and shrubs growing in the channel reduce the rate of flow causing sediment to accumulate. If the trenched channel continues to fill with sediment, flooding of adjacent lands will be more frequent; consequently, a smaller channel with wider meanders would develop over the adjacent to the present channel. Channel plugs have been used in the past to hasten this process. Land management agencies have constructed floodwater spreaders at several locations in the Northern Great Plains to achieve the same results.

A logical plan for reconstruction of valley floors would consider optimum use of floodwaters and entrapment of sediment. Analysis of data acquired at the various study sites provide insight as to how to best use available resources to accomplish this purpose. Grasses rather than the shrubs now occurring in the area should be planted if optimum forage production from the flood plain and low terraces is desired. Grasses characteristically occupy areas that are frequently flooded. Western wheatgrass, which is native to the area, is capable of withstanding up to one foot of sediment deposition per year.

Silver sagebrush now occurs on alluvium with low to moderate moisture-retention capabilities while greasewood occurs on alluvium with higher retention capabilities. Ground water is apparently utilized by both species, with indications that their roots transport and supply water for recharge of soil some distance above the water table. Before mining, these shrubs could be used as indicators to help delineate alluvial deposits with different moisture-retention capabilities. As a result, different materials could be stockpiled separately.

Highly retentive alluvium associated with greasewood should be considered for use in reconstructing the flood plain. There is evidence that such fine-textured alluvium can support a good cover of western wheatgrass if flooded frequently.

Moderately retentive alluvium associated with silver sagebrush should be considered for positioning on reshaped uplands; there is evidence that, when sagebrush has been eradicated from similar soils, grass can simply be seeded and established. This could eliminate the need to hold water on the surface by furrowing, as would be required if highly retentive soil is placed at the surface on upland areas.

Reconstruction of upland soils with properly selected materials can result in more efficient utilization of soil moisture by vegetation than that which usually occurs under natural conditions. At some of these sites, bedrock encountered at different depths impedes drainage causing moisture to be stored in thicker than normal films. The force with which moisture is adsorbed decreases 2.46 times for each additional molecular layer of water adsorbed. Consequently, water is more readily obtained by vegetation. Under these conditions, less hardy but more productive species of vegetation occur under natural conditions.

Placement of required depths of loamy soil over properly compacted finer materials, as previously proposed, can result in more efficient use of soil moisture by vegetation. Available fine-textured materials should be used to cover unweathered spoil. This finer material should be compacted to the degree where void-moisture capabilities (VMC's) determined from volume weight (VW) measurements, are less than the moisture-retention capabilities (MRC's) of the materials. Moisture-retention capabilities of materials can be readily evaluated using a filter paper method and a modeling technique. Fifteen atmosphere moisture content data, characteristically published by the U.S. Soil Conservation Service, can also be used in conjunction with a modeling technique to define moisture-retention capabilities (MRC's) of soils.

With the moisture-retention capability (MRC) of available soil material at hand, the depth of soil that must be repositioned to obtain desired results can be determined. The depth of loamy material that must be deposited over finer-textured base material will also be dependent on the degree of compaction. Once the amount of water likely to infiltrate is determined, the depth of material with a given retention capability (MRC) and the volume weight (VW) needed to achieve desired results can be determined. The maximum depth of water stored in upland soils averaged 10 inches (25 cm) at sites sampled in the Hanging Woman study area. This value includes data for sites where snow blows off and data from sites where wind-blown snow accumulates. Snow movement could be minimized by properly shaping the land and managing the vegetation for moderate to high stubble length. Also, upland soils could be reconstructed to store 10 inches (25 cm) of water when wetted to the adsorption-moisture capacity (AMC) (16 molecular layers of water).

Under these conditions, six molecular layers of water are adsorbed to particle surfaces in excess of the 10 layers present when unimpeded drainage stops at the moisture-retention capability (MRC) level. Maximum levels of storage would probably not be achieved except during the wettest years; nevertheless, storage of some water in excess of 10 molecular layers would probably occur during all but the driest years. As a result of increased water availability, midgrasses rather than shortgrasses should dominate the reconstructed area. If the area is not overgrazed, this taller vegetation should also help hold snow where it falls.

Compaction, resulting from repositioning of soil with machinery, can result in volume weights (VW's) that do not provide sufficient void space for infiltration and storage of water; consequently, the volume weight (VW) that must be achieved to permit storage at adsorption-moisture capacity (AMC)

levels must be determined prior to positioning of materials. For example, if retention capability (MRC) of the loamy material used to reconstruct the solum is 10%, the adsorption capacity (AMC) will be 16%. The volume weight (VW) required to produce a void-moisture capacity (VMC) of 16% can be determined from the linear relationship between volume weight (VW) and void-moisture capacity (VMC).

Lower volume weights (VW's) would be necessary to provide the proper void space in soils with higher moisture retention capabilities (MRC's). If a soil is too compact after emplacement, the required voids can be created by causing a total of 10 inches (25 cm) of water to accumulate in the soil. This could be accomplished by a series of sprinkler irrigations, or perhaps by causing snow to accumulate behind a set of movable snow fences. The fence could be relocated after desired results are obtained. If soils with high retention capabilities (MRC's) must be used instead of loamy materials, catchments should be created at the surface with an Arcadia furrower.

Moisture regimes occurring in breaks and foot slope areas will be difficult to reestablish because of the complexity of these areas caused by variable erosion and deposition of sediments and variable depths to parent rock. The steep slopes, characteristic of breaks, could probably not be maintained unless resistant rocks were deposited there rather than softer soil materials. The parent rock encountered at the base of soil profiles tends to disintegrate readily when saturated with water. Some desirable soil materials may be available from this source. Moisture-retention characteristics of these materials can be defined by techniques described in this report.

Overburden

If there is not sufficient topsoil at the site, then the overburden rock will have to be considered as a substitute.

Perhaps the single most important statement to be made about the lack of potential chemical harmfulness of a potential soil replacement material (overburden rock) is that it is chemically and mineralogically similar to soils of the region which successfully support desirable stands of the native vegetation. The sandstone, and to a somewhat lesser extent the siltstone-plus-shale, at the Hanging Woman study site is similar in bulk chemistry to the subsoils at the study site and the rest of the Fort Union region.

Judged only from bulk chemistry of rock and soil samples, it appears that much of the overburden rock at the Hanging Woman Creek study area could be used to replace the soils of the site or region. It is, however, probable that the pulverized overburden, during its process of chemical weathering and physical alteration in its new, near-surface environment, would release different quantities of chemical substances than would the natural soils: the pulverized rock could be expected to release either

more or less, depending on the substance at its mineralogical form in the rock. These questions of the amounts of chemical substances which would be released by pulverized overburden material used as soil replacement can only be resolved by studies of chemical-leach elemental availability, by studies of physical properties and breakdown, and perhaps by plant uptake studies conducted on the pulverized rock material.

We plan to conduct availability tests on the samples of this study. The equally important study of physical properties and physical alteration with time must come from other workers. At the present limited stage of knowledge of reclamation chemistry and toxicity of elemental concentrations in soil, we feel that it is a very complex matter to get actual "red flag" or hazard level concentration limits in soils for particular elements. Some progress has been made in this matter for certain elements, most notably molybdenum and selenium, but for these and almost all other elements of interest, different soil conditions and even different points of view have the strongest influence on the assignment of maximum permissible levels. Varying soil pH, mineralogy, moisture regime, and temperature, as well as the varying uptake abilities of different plant species and the hardiness and dietary preferences of various animal species, must be taken into account in determining acceptable ranges of whole-soil concentrations of chemical elements. The situation is only somewhat simpler for determining acceptable availability levels of the elements.

In general, sandstone is sufficiently abundant (about one-third of the overburden rock) and is present in sufficiently thick, continuous and recognizable units to be used as the sole type of overburden reclamation material wherever that would seem desirable, as for a plant growth medium on the top of the refill column, or for the material most likely to contact ground water at the bottom of the refill column. In much of the overburden rock column, strata of siltstone are sufficiently thick to be treated in the same way, if desired. Units of dark shale and other shale are more commonly intermixed with each other and with sandstone and siltstone over short vertical distances, but the relative volumes of either pure or intermixed zones of shale are small enough that these rocks could practically be segregated into the middle part of the refill material and separated from both plant roots and the ground water zone by a thickness of sandier rock at top and bottom.

Other USGS studies are being conducted to assess the effects that may occur through surface mining on plants themselves, rather than indirectly via availability measurements of the spoil materials. It has been reported that spoil material, even with topsoil added, affects the element concentrations of plants to a significant degree relative to plants grown in undisturbed areas. Some of these effects may be beneficial; others could pose some nutritional problems to animals feeding on the plants. These conclusions are based on studies of sweetclover, several cool-season grasses, alfalfa, and wheat (plants commonly used in reclamation) samples from reclaimed lands of selected mines and from "control" areas in the Northern Great Plains coal region.

These studies tend to corroborate an earlier analysis, which found the phosphorus available to plants to be very low in spoil materials from the Northern Great Plains. Conversely, zinc concentrations appear to be increased in plants growing on spoils, an effect that may be beneficial. A potential range management problem arising from use of forage plants growing on spoil is that the copper:molybdenum ratio in such plants is rather consistently less than about two, the value below which molybdenosis is considered likely to affect ruminants, particularly cattle.

The mineralogy of the soil materials does not suggest any problems of slope instability with the possible exception of those soils that may have a combination of abundant montmorillonite and available sodium ions. The sodium-saturated clay is subject to enhanced expansion and contraction as the clay undergoes a wetting-drying cycle. Such high-sodic clays should be selected and placed on only level to moderate slopes and beyond the depth of plant roots.